GOVERNMENT OF PAKISTAN
COMMUNICATIONS DIVISION
NATIONAL TRANSPORT RESEARCH CENTRE

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HIGHWAY MAINTENANCE MANAGEMENT

NTRC-198

Mumtaz Hussain Malik
Assistant Chief

May, 1997

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EXECUTIVE SUMMARY

Highway maintenance management is an important issue especially with reference to road deterioration. A well maintained road system plays a vital role in achieving social and economic benefits and the road does not fail before the end of its design life. Maintenance reduces the rate of deterioration and it lowers the cost of operating vehicles on the road by providing a smooth running surface.

Even with adequate maintenance, roads will deteriorate over time. The rate of deterioration will depend on a number of factors including traffic loading, road strength and climate.

Maintenance of a highway is started as soon as it is opened to traffic and continued till the end of design life. For this purpose the initial step is to record the basic characteristics of each section of the road network, containing all relevent data which influence maintenance needs.

Another important step in highway maintenance is road inspection which must define where deterioration is occuring, measure the extent of the problem and suggest the action needed to put matter right. The maintenance engineer responsible for inspection has a key role in achieving the task of proper management, therefore he should be trained in visual assessnent of defects and in measurement techniques.

Various maintenance activities are carried out at different stages. It is very important to Clearly define the intervention level for a particular road or network at the outset. there is considerable economic benefit in carrying out appropriate maintenance at the right time as deferring one activity results in a rapid deterioration, causing escalation of costs.

There are five different maintenance types required depending on the type of deterioration. These include (a) routine maintenance (b) periodic maintenance (c) recurring mintenance (d) rehabilitation maintenance and (e) emergency maintenance.

An ideal way of highway maintence is to adopt a policy of stage condition survey. Every year the whole network may be covered by rapid and cheap surveys. Secondly structural survey may be done for 20% of the network, and thirdly detailed investigation may be carried out for at least 5% of the network.

One of the most important responsibility often ignored by our maintenance organizations is proper supervision of field works.

The problem of allocating funds on the basis of real needs and by means of an overall economic justification is of primary importance. The maintenance funds are often diverted to new construction and are spread thinly over the entire network which results in wasting of money.

Clearly, the preservation of the road network as a national asset justifies the considerable expenditure involved the maintenance. There must be an established road maintenance policy with adequate funds, skilled manpower and equipment to do the job.

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CHAPTER - I

INTRODUCTION

1.1 Objective of the Study

The main objective of the study is to point out the management principles which may be used in order to maintain roads and to keep them at a reasonable serviceability level. Particular attention would be given to road deterioration level and level of intervention in order to bring down VOC. A huge amount of foreign exchange is spent on reconstruction of roads which are damaged due to improper maintenance. Various maintenance activities would be pointed out which are very much required to be introduced in our country. There is hardly any section of highway where proper maintenance is being done. Emphasis would be given for involvement of maintenance engineers in inspection and monitoring of site. There are latest techniques being used in developed as well as developing countries which are locally adaptable and also repay their cost economically as well as financially. A brief description of the maintenance management techniques used by NHA would be given.

1.2 Purpose of Highways maintenance

The purpose of maintenance is to ensure that the road does not fail before the end of its design life. Maintenance reduces the rate of road deterioration resulting in reducing the cost of operating vehicles on the road by providing a smooth running surface. It keeps the road open on a continuous basis by preventing it from becoming impassable. It is a relatively low cost activity and specifically excludes those works designed to increase the strength or improve the alignment of the road. Highway maintenance is a series of activities aiming to keep the condition of road to a acceptable level of safety and comfort of users. When a road is operated under the toll scheme the emphasis should be given to maintain the serviceability level at a higher grade to optimize the user's benefits by means of safety and comfort as to off set the tax they pay for it. On the other hand the economic use of resources is required to keep the profit of toll road operator satisfactory. The best strategy to keep the major expenditures down is to well attend and carry out maintenance looking at the changing conditions and to find out the early and timely solution of it.

Benefits arising from road improvement.

Types of Benefits	Accrues to
Changes in travel time	Road user
Changes in VOC	Road user
Changes in accident costs	Road user including pedestrian, Central and Local government, relative and friends to those at risk.
Environment impact Noise pollution, Visual intrusion, Severance.	The community at large, people living near affected roads.

1.3 Definition of maintenance terms

The following definition are generally used

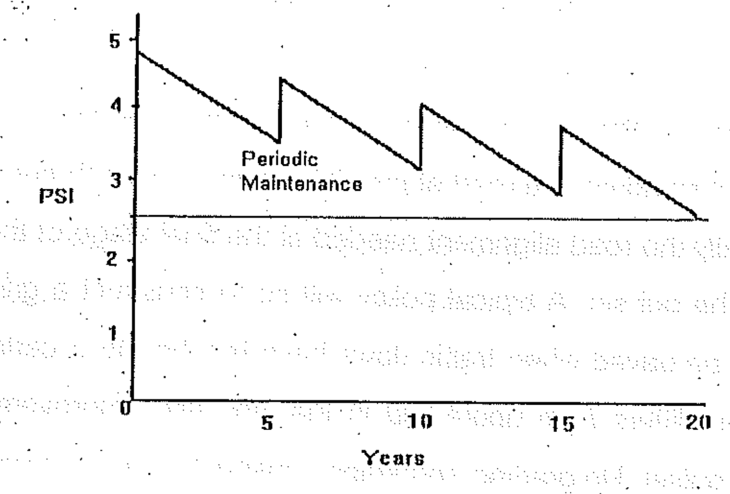
a) **Upgrading :** It aims at providing additional capacity when a road is nearing the end of its design life or because there has been an unforeseen change in the use of road. Typical examples of upgrading projects are the paving of gravel roads, the provision of strengthening overlays for paved roads and the widening of roads.

b) **Stage Construction :** Stage construction consists of planned improvement to the initial pavement standard of a road at pre-determined stages through out the project life. Normally the road alignment needed at the final stage of the project is provided from the out set. A typical policy will be to construct a gravel road initially which will be paved when traffic flows have reached to a certain level. Stage construction differs from upgrading in that any later improvements are planned from the outset. Up grading and stage construction are not undertaken without a proper assessment of maintenance capacity.

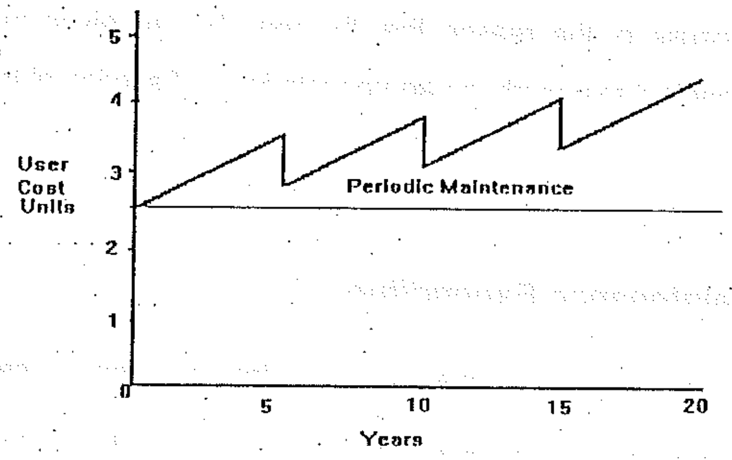
c) **Rehabilitation :** Rehabilitation is needed if the road has deteriorated beyond the condition at which overlaying is satisfactory engineering alternative. This may often be because of the reason that the road has received insufficient maintenance to enable it to provide an appropriate level of service at the end of its design life.

1.4 Justification of Maintenance Expenditure

The serviceability of a pavement is a measure of its state of fitness to carry traffic comfortably, safely and economically. It is assessed from structural condition of pavement and its functions are rutting, cracking and roughness which justify the maintenance expenditures. User cost is inversely related to the level of serviceability and it goes up as the road roughness increases. The two graphs given below show the VOC relation with the serviceability level. The following few points give the justification of maintenance expenditures.



Level of Servicibility for a Toll Road



User Cost Versus Servicibility

1.4.1 Reducing Road Deterioration : Roads will deteriorate over time even if there is adequate maintenance. The rate of deterioration will depend on a number of factors including traffic loading, road strength and climate. Eventually at the end of the design life, there is a need for strengthening or reconstruction which are very expensive activities and should therefore be postponed for as long as possible by carrying out effective and timely maintenance.

If routine maintenance is not carried out surface defects worsen causing water penetration into the road structure. Due to road distress premature periodic maintenance is required which is atleast twenty times more costly than routine maintenance. If periodic maintenance is not carried at this stage, road leads to the need to carry out road strengthening which is at least three times expensive than periodic maintenance. If this strengthening is not carried out soon enough major deterioration takes place that rehabilitation will be required which is five times more costly than strengthening. Clearly, there is considerable economic benefit in carry out right maintenance activity at right time.

1.4.2 Axle Loading : The effect of overloading on road maintenance is considerable. An axle weighing 16 tones does 20 times as much damage as an 8 tones axle. For the purpose of road maintenance, it is essential to know the value of the actual axle loading on a road as minor under estimates can considerably shorten the expected life of a road. From a road maintenance point of view there is considerable advantage in having appropriate axle load legislation which is effectively enforced. There are many problems associated with the enforcement of axle load legislation. But whether axle load limits are enforced or not It is of significant importance for the road maintenance organization to know the magnitude of the axle loads actually being carried by roads so that maintenance planning can be carried out effectively.

Average Axle Loads (Tones)

Truck Description	Front	Rear1	Rear2	Rear3	Rear4	Rear5	Gross
2-Axle Single	4.93	11.13					16.06
3-Axle single	6.74	12.59	12.17				31.51
3-Axle tandem	6.74	12.37	12.51				31.61
4-Axle rear Tandem	5.39	11.50	10.90	10.75			38.53
5-Axle Tandem	5.55	9.28	9.28	10.27	10.95		45.33
6-Axle Tandem Tridem	6.43	10.37	10.67	10.49	10.99	10.50	59.45

Source -Axle load study by NTRC -1995

1.4.3 To reduce Vehicle Operating costs : Costs of operating vehicles depend on the surface, condition of the road. If the roads are designed in such a way that provided maintenance and strengthening can be carried out at the proper time, the total cost which mainly depend on user costs can be minimised. The cost of vehicular travel is reflected in almost all walks of life, high transport cost means less competitive exports and reduced economic activity. If a road is badly monitored with a rough or pot holed riding surface, the cost of vehicles traveling on the roads are increased due to:

a) Using more fuel.

b) Transporting less goods in a given time.

c) Increased repair and maintenance costs.

d) Increased tyre wear.

e) Shorter vehicle life.

Cost saving achieved by deferring the need for rehabilitation exclude the benefits to operators by avoiding the high cost of operating on badly deteriorated roads.

Economic VOC Rs/1000 Km (1993 prices)

Veh Type	Spd Kmh	V good r-2500	good r-3000	fair r-3500	poor ggrvl r-5000	v poor g/rth r-7000
MCY	30	797	802	808	855	904
CAR	60	2546	2583	2789	3014	3273
WGN	50	3473	3583	3695	4143	4676
BUS	40	7838	8061	8276	9273	10465
TRK	30	5790	5856	5924	6758	7641
MXL	30	7261	7357	7454	8504	9632
TRL	30	8713	8828	8941	10233	11618
MCY	50	614	620	628	678	733
CAR	90	2599	2645	2806	3142	3522
WGN	80	3469	3601	3733	4257	4888
BUS	60	6517	6747	6966	8012	9257
TRK	50	4111	4182	4254	4822	5444
MXL	50	5226	5332	5435	6174	6996
TRL	50	6308	6439	6562	7475	8491

Source -National Transport Plan 1995 (Jica)

1.4.4 To Keep the Road Open : If roads are closed due to flooding, Landslides, culverts or bridge failure or by surface becoming impassable, communications are disrupted with serious social and economic consequences. Generally expensive efforts are always made to restore communications in the minimum time. It is a fact that many such emergencies could be prevented if attention is given to the standards of regular inspection and maintenance action.

Freight traffic Highways versus Railways

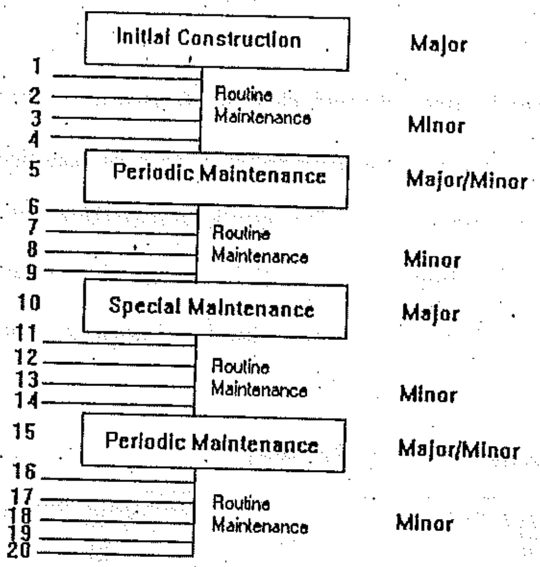
Year	Highways %age	Railways %age
1971-72	50	50
1980-81	70	30
1992-93	84	16

Source-NTP by JICA & 8th five year plan.

If road is closed vehicles would not be able to reach their destination which may result in social cut off and closure of factories due to non-availability of raw material. There would be no good manufactured. Agriculture would suffer in a similar way because of lack of fertilizers and the failure to self produce. This could bring down foreign exchange earnings due to reduction in exports in national calamity.

1.5 The Types of Maintenance

For convenience in planning and budgeting maintenance and for the purposes of management the most useful way to classify maintenance activities in terms of their frequency, there are several categories.



a) **Routine Maintenance** : Operations carried out at regular intervals e.g. repairing shoulder, cleaning culverts, repairing pot holes, repairing, verges, slopes, signals, sign posts, road marking, barriers, lighting facilities, removal of debries from the carriage way, clearance of snow and ice and grass cutting etc.

b) **Periodic Maintenance** : Operations carried out at intervals of more than one year i.e. Renewal or renovation of the wearing surfaces of carriage ways that become worn or deformed by use e.g. resealing, overlaying and surfacing dressing, regravelling of unpaved roads.

c) **Rehabilitative Maintenance** : Operations required to bring a deteriorated road back up to the original standard. Typically, they are strengthening and or reconstruction of a pavement structure, major actions to protect roads against internal agents, e.g. actions involving slope stabilization and land sliding/rock falling retaining walls and protection against flooding.

d) **Improvements** : Minor improvements, widening etc. which are too small to involve a construction unit.

e) **Emergency Repairs** : Repairs required immediately to restore communications, removal of debris and other obstacles, placement of warning sign and diversion works.

1.6 Maintenance by Order of Importance

Maintenance activities may be ranked in the following order of importance.

Urgent Emergency repair, removal of debris and stabilization of side slopes. By definition, urgent works of this type demand top priority.

Routine Drainage Work Cleaning out and recutting ditches and turn outs, cleaning out bridges and culverts, filling scoured areas, repair of drainage structures. This work always deserve high priority because neglected drainage can rapidly lead to deterioration of the whole road. It is important to rectify the drainage otherwise the repairing surface defects caused by poor drainage will be a waste of time & effort.

Recurrent Work Dragging, brushing, grading or filling of unpaved road, patching or local sealing of paved roads. These are important for controlling further deterioration.

Periodic Work Regravelling of unpaved roads surface dressing of paved roads. Periodic work can be treated as a series of distinct projects that have to be completed within the resources available and can be undertaken separately, deferred or brought forward as required.

Special (Overlaying, Reconstruction) These activities should be treated as capital projects whose funding does not come out of the maintenance budget.

1.7 Roads by Orders of Importance

The roads that carry the heaviest loads of traffic form the most important parts of the network from an economic stand point, and they are the roads liable to deteriorate most rapidly due to wear and tear. There may also be roads with relatively low levels of traffic which nevertheless have key strategic importance because of the places they link. Since it is vital to keep these strategically important roads in good condition, it makes sense to give them top priority for maintenance. The remainder of the network should be classified by the level of traffic on each road. This level is usually expressed in terms of the estimated annual average daily traffic (AADT).

1.8 Role of Maintenance Engineer

The maintenance engineer should be able to collect basic information to determine priorities and draw up purposeful program which will enable the required work to be carried out in a systematic and cost effective way. The maintenance engineer is one of the key person in any maintenance organization, who is responsible for running the organization at operational level. The first essential in any road maintenance system is to have a workable road inspection system by which Engineering staff may make regular inspections of the road network and assess the work required. A simple road condition survey form should be used and survey carried out carefully and consciously by teams walking along the road.

Survey should be done at not less than annual intervals. The best time for conducting surveys is during the rainy season when the roads are at their weakest condition. In addition to the road condition survey data it is necessary to determine the volume and types of traffic. The maintenance Engineer should take keen interest in the maintenance work by regularly inspecting the roads under his control and making his staff aware of his interest.

By going into the field the Engineer would be able to get to know his road network thoroughly and will readily identify trouble spots and other area of difficulty. He must also see the quality of the maintenance work carried out. Areas which require strengthening or overlaying may require additional structural strength surveys such as dynamic cone penetrometer, Benkelman Beam, deflection and axle load surveys results. These are normally not responsibility of the maintenance Engineer but carried out at main organizational level. From the recorded survey data the amount of work required on any road may be assessed and approximate quantities calculated. It is better to store data on micro computer to make it more convenient to check the rate of deterioration of a particular section.

1.9 Priority Budgeting for Maintenance

Of the roads budgets available in developing countries, very little is normally allocated to maintenance. Governments should, therefore, reduce the amount of new construction and spend on improvement of existing roads. The priority allocating should be preventative and periodic maintenance. Any funds available after this should be used for reconstruction of pavements that have failed due to lack of maintenance. After the improvement of existing roads the available funds should be spent on new construction. The closure/abandoning parts of the road network has serious political and social implications for the governments. It can be seen from the following table that the actual release on maintenance have not been at par with the maintenance requirement.

Maintenance requirement 1989-90/1995-96 **(Rs. Million)**

Financial Year	Demand based on actual needs	Amount allocated	Expenditure
1987-88	347.000	180.000	180.000
1988-89	422.770	200.680	200.680
1989-90	474.500	268.850	268.850
1990-91	600.000	281.595	281.595
1991-92	795.500	378.000	378.000
1992-93	930.000	410.000	410.000
1993-94	1097.000	430.500	430.500
1994-95	1317.000	452.000	452.000
1995-96	1554.000	475.000	427.000

source - NHA maintenance report 1995-96

At this stage of time the maintenance grant is only 30% of the requirement. According to the NHA if maintenance funds on the national network are not enhanced in the next five year plan some 45%- 55% of the present National Highways network of 6,200 Km would require reconstruction at the start of the 10th five year plan.

In the maintenance directorate resources are always very limited. A maintenance Engineer is very fortunate if he finds that he has all the resources he needs to carry out the full program of work, otherwise he has to decide the most effective way of applying them, this means working out an order of priority, with the operations that have the strongest claim on resources placed at the head of the list and those that have least claim placed at the end. This relates the importance of the maintenance activity to the importance of the road. It involves two basic questions :

i) how critical is a particular maintenance to the traffic?

ii) how significant is the particular road as a transport link?

CHAPTER - II

ROAD DETERIORATION AND INTERVENTION

2.1 Type of Pavement Failure

Sl No	Mode	Manifestation	Mechanism	Possible types of treatment
1.	Fatty surface	Collection of binder on the surface	Excessive binder in premix, spray or tack coat: loss of cover aggregates, excessively heavy axle load.	Sand-blind; open-graded premix, liquid seal coat; burning of excess binder; removal of affected area.
2.	Smooth surface	Slippery	Polishing of aggregates under traffic, or excessive binder.	Resurfacing with surface dressing or premix carpet.
3.	Streaking	Presence of alternate lean and heavy lines of bitumen	Non-uniform application of bitumen, or at a low temperature.	Application of a new surfaces.
4.	Hungry surface	Loss of aggregates or presence of fine cracks	Use of less bitumen or absorptive aggregates.	Slurry seal or fog seal.
5.	Hair-line crack	Short and fine cracks at close intervals on the surface	Insufficient bitumen, excessive filler or improper compaction	The treatment will depend on whether pavement is structurally sound or unsound. Where the pavement is structurally sound, the cracks should be filled with a low viscosity binder or a slurry seal or fog seal depending on the width of cracks. Unsound cracked pavements will need strengthening or rehabilitation treatment.
6.	Alligator crack	Inter-connected cracks forming series of small blocks	Weak pavement, unstable conditions of subgrade or lower layers, excessive overloads or brittleness of binder	Same as serial no 5
7.	Longitudinal crack	Cracks on a straight line along the road	Poor drainage, shoulder settlement, weak joint between adjoining spreads of pavement layers or differential frost heave	Same as serial no 5

8.	Edge crack	Crack near and parallel to pavement edge	Lack of support from shoulder, poor drainage, frost heave, or inadequate pavement width	Same as serial no 5
9.	Shrinkage crack	Cracks in transverse direction or inter-connected cracks forming a series of large blocks	Shrinkage of bituminous layer with age	Same as serial no 5
10.	Reflection crack	Sympathetic cracks over joints and cracks in the pavement underneath	Due to joints and cracks in the pavement layer underneath	Same as serial no 5
11.	Slippage	Formation of crescent shaped cracks pointing in the direction of the thrust of wheels	Unusual thrust of wheels in a direction, lack or failure of bond between surface and lower pavement courses	Removal of the surface layer in the affected area and replacement with fresh material.
12.	Rutting	Longitudinal depression in the wheel tracks	Heavy channelised traffic, inadequate compaction of pavement layers, poor stability of pavement material or heavy bullock cart traffic	Filling the depressions with pre-mix materials.
13.	Corrugations	Formation of regular undulations	Lack of stability in the mix, oscillations set up by vehicle springs, or faulty laying of surface course	Scarification and relaying of surfacing, or cutting of high spots and filling of low spots.
14.	Shoving	Localised bulging of pavement surface alongwith crescent shaped cracks	Unstable mix, lack of bond between layers, or heavy start-stop type movements and those involving negotiations of curves and gradients	Removing the material to firm base and relaying a stable mix.
15.	Shallow depression	Localised shallow depressions	Presence of inadequately compacted pockets	Filling with premix materials
16.	Settlement and upheaval	Large deformation of pavement	Poor compaction of fills, poor drainage, inadequate pavement or frost heave	Where fill is weak the defective fill should be excavated and redone. Where inadequate payment is the cause, the pavement should be strengthened.
17.	Stripping	Separation of bitumen from aggregates in the presence of moisture	Use of hydrophilic aggregate, inadequate mix composition, continuous contact with water, poor bond between aggregate and bitumen at the time of construction, etc.	Spreading and compacting heated sand over the affected area in the case of surface dressing;replacement with fresh bituminous mix with added antistripping agent in other cases.

18.	Loss of aggregate	Rough surface with loss of aggregate in some portions	Aging and hardening of binder stripping, poor bond between binder and aggregate, poor compaction etc.	Application of liquid seal, fog seal of slurry seal depending on the extent of damage.
19.	Raveling	Failure of binder to hold the aggregates shown up by pock marks of eroded areas on the surface.	Poor compaction, poor bond between binder and aggregate, insufficient binder and aggregate, insufficient binder, brittleness of binder etc.	Application of cutback covered with coarse sand, or slurry seal, or a premix renewal coat.
20.	Pot-hole	Appearance of bowl shaped holes, usually after rain	Ingress of water into the pavement, lack of bond between the surfacing and WBM base, insufficient bitumen content etc.	Filling pot-holes with premix material, or penetration patching
21.	Edge-breaking	Irregular breakage of pavement edges	Water infiltration, poor lateral support from shoulders, inadequate strength of pavement edges, etc.	Cutting the affected area to regular sections and rebuilding with simultaneous attention paid to the proper construction of shoulders.

2.2 Assessment of Maintenance Capabilities

There are several ways of assessing the existing maintenance capacity of a roads organization. Any competent road Engineer should be able to make a subjective assessment by simply inspecting a sample of roads. Lack of effective maintenance will be shown by the level of deterioration of the road network taken as a whole. Watching maintenance gangs working in the field will also give a good indication of the likely productivity and durability of maintenance operations. Field measurements can be taken several functions and these should be used in conjunction with available records from the road maintenance organization to enable the assessment of capability to be made. Records should be collected and compared with field measurements of productivity rates for selected maintenance activities.

2.3 Assessment of Maintenance Needs

For assessment of pavement condition and maintenance needs at various parts of the network and with the purpose of identifying work that needs to be done it is necessary to carry out condition measurement survey of the entire road network. For the purpose of routine, recurrent and periodic maintenance, this requires that inspectors walk all of the roads and carry out simple measurements of road condition. The condition measurements obtained in this way can then be compared with economically based intervention level to determine maintenance needs. For paved roads the relationship between the rate of pavement deterioration and the level of maintenance is very sensitive to complex variation in the parameters of traffic loading, climate, and pavement material etc. These relationships have still to be quantified adequately. The maintenance requirements identified should be objective and funds may be allocated equitably between the various regions. In this way the results of condition assessments can and should be used as the basis for allocation of funds.

The consequences of a shortfall in allocation can be demonstrated in terms of the effect on the country's economy in general. It is often felt that for a maintenance engineer gathering data represents a significant work load in its own right. There is often a temptation to reduce the amount and scope of data gathering when maintenance funds are tight. This should be resisted where possible as adequate maintenance records are in many ways the key to credibility and, consequently, good road maintenance. At the same time, it must be remembered that when establishing a maintenance data bank, perhaps the most difficult management problem to overcome is that of defining precisely what information is required to meet management objectives and to refrain from asking for more data then is really necessary. It is easy to call for data, it is relatively easy to acquire and store data, it is possible to devise computer programme for the retrieval of the data at reasonable cost, but it is by no means easy to decide at the out set what data are immediately essential, what are likely to be required in future years, and what would be useful if acquired.

2.4 Rapid Method of Assessment

The assessment of maintenance needs has already been described though these satisfy all the basic requirements of objectivity and rationally these are needed. However, the introduction of such a system of assessment can prove difficult and can take a long time to implement. It will be necessary to develop optimum intervention level for the country to produce an inventory of the network. This will provide the basis for the inspections and to train and equip staff to carry out the inspection and a system for recording and analysing the data collected. Although the introduction of such a system should be a target for all countries, it will probably be necessary to adopt an interim method which can be used whilst the final system is being introduced. As an interim measure it is probably only possible to rank roads according to their condition and to carry out physical condition surveys at a sample of points to enable the required maintenance works to be determined.

2.5 Road Inspection

Procedure for field inspections should emphasis on the condition of the pavement rather than its basic characteristics. They identify locations where deterioration is occurring, measure the extent of the problem and define the action needed to put matter right. It is likely that, while the management system is being developed, the early inspections will have to rely largely on a visual assessment of defects but measurement techniques should be introduced as soon as it is practical to do so. The basic objective of these inspection is to assess current maintenance needs, to check the effectiveness of maintenance work.

For developing countries the approach of inspecting the whole network at least once every six months is quite effective. This means one inspection during the Wet season and one during dry season when carriage way is Wet defects like surface cracking and drainage system are easy to identify. Pre printed forms are normally used for inspections as they remind the inspector of items to be considered. Whatever form is used it should be easy to understand and apply.

2.6 Factors Affecting Maintenance Inspections

Pavement defects which normally require immediate action, particularly if they constitute an imminent hazard, include:-

(a) pot holes and other local defects in the carriage way.

(b) curbing, edging and channel defects.

(c) excessive standing water and water discharging into and or flowing across the highway.

(d) damaged safety fences and other barriers.

(e) debris and spillage in traffic lanes or on hard shoulders.

(f) damaged lighting columns and other street furniture.

(g) damaged, defective, displaced or missing traffic signs or signals.

(h) dirty or otherwise obscured traffic signs and signals.

(i) trees, shrubs and hedges which by virtue of their position constitute a hazard to road users. The assessment of many defects and maintenance needs is necessarily dependent upon the maintenance engineers view of what is satisfactory what represent failure etc. and upon the inspector's interpretation of the engineer's policies with respect to these. Maintenance standard acceptable for a road system in a developing country are not necessarily those which would be used in a highly industrialized country. Maintenance standards indicate the remedial action that need to be carried out as well as indicating the nature & scale of the maintenance defect or problem, a well defined standard will assist in describing the remedial action to be initiated.

2.7 Intervention Levels on Paved Roads

The maintenance engineer must interpret the inspection results so as to decide when and where repairs are needed and what form of maintenance activity is required. Like a doctor treating an illness, he has to recognize the symptoms that indicate it is time to take remedial action. These indications are termed as intervention level; i.e. they identify the stage or circumstance in which the maintenance engineer should intervene and the action he should take to stop further deterioration. It is advisable always to adopt intervention levels suited to the particular local conditions. The recommended intervention levels should be based on the assumption that the road network is already being maintained to an adequate standard and that sufficient resources are available to keep up this standard. In other words, they represent a target that the maintenance engineer should aim eventually to achieve. If, as will often be the case, he has too few resources at his disposal to apply the recommended levels, he can adopt alternative levels that are more appropriate to the work load and capabilities of his organization.

2.8 Diagnozing the Causes of Deterioration

Pavements deteriorates due to traffic and environmental factors. The extent of deterioration is also a function of the initial pavement thickness and composition. The exact way in which a pavement deteriorates is of great importance to a maintenance engineer to work out the maintenance strategy and to a highway planner to work out the economic evaluation of schemes. It is important to identify the cause of deterioration and to put this right if possible, rather than just treating the symptom. For example, there is little point in continually filling in pot holes in a road if they keep occurring only because of poor drainage. Finding the real problem and focusing attention on its solution will produce a more cost effective use of maintenance resources. Some problems of course may be outside the scope of maintenance. For example a road across flat country with inadequate drainage out falls may experience base failure as a result of the capillary rise of water in the Wet season. The only solution to the problem is to raise the level of the road. This would be a road improvement, not a maintenance operation as such, it may warrant a special allocation of resources in accordance with the organization's procedures for road improvement work.

road

CHAPTER III

PAVEMENT EVALUATION

3.1 What is pavement evaluation?

Pavement evaluation is a technique of assessing the condition of a pavement, both structurally and from the point of view of surface characteristics. It is also known as pavement condition survey and rating of pavement. Pavement evaluation serves a variety of purposes, such as :

a) To research on the performance of pavement of different specifications over a period of time.

b) To assess maintenance need such as patch repairs, renewals and resealing.

c) To assess the need for structural overlays on distressed pavements.

3.2 Methods of Pavement Evaluation

For carrying out a comprehensive evaluation of the condition and performance of a ɔavement the following flow diagram can be used as a guiding principle. The full process ıay not be necessary, depending upon the needs of the scheme at hand.

<u>quential process of structural examination for a bituminous pavement.</u>

'ection and visual condition survey.

ɔction preparatory information

fy at least two sections exhibiting different degrees of distress and select test areas

ests Deflection beam Rut depth Crack survey Sample of cores Trial holes (e.g. CBR, ınetrometer) Topography Drainage check.

ɔry tests Material composition Strength properties(e.g. CBR)

n of test data and other evidence.

s on causes and effects.

Theoretical analysis.

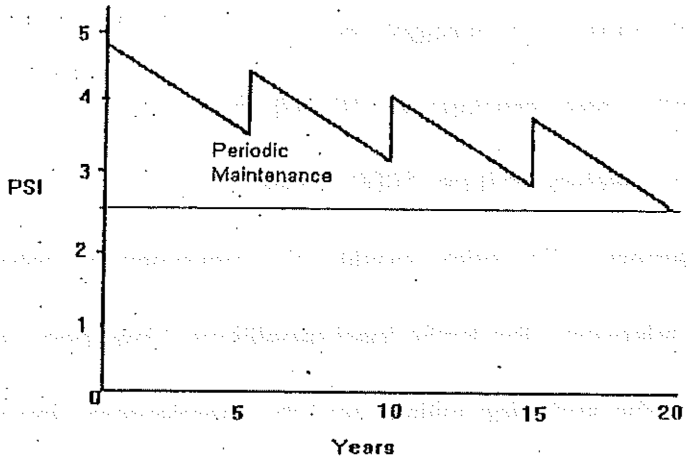
The methods available for pavement evaluation are:.

3.2.1 Visual Rating: Visual rating is a simple method of inspecting the pavement surface for detecting and assessing the amount and severity of various types of damage. The distress which can be rated visually are : rutting, corrugations, raveling, flushing, alligator cracking longitudinal cracking, transverse cracking etc. and extent of their repairs. Various organisation have their own level and standards. TRL describes the structural condition of road mainly depending on Rutting, and Cracking into three states i.e. sound, critical or failed as given below.

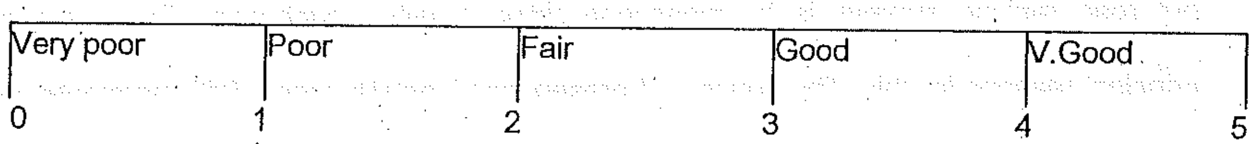
Classification of the condition of the road surface

classification	Code	Visible evidence
Sound	1	No cracking. Rutting under a 2m straight edge less than 5mm.
	2	No cracking. Rutting from 5mm to 9mm.
Critical	3	No cracking. Rutting from 10mm to 19mm.
	4	Cracking confined to a single crack or extending over less than half of the width of the wheel path. Rutting 19mm or less.
Failed	5	Interconnected multiple cracking extending over the greater part of the width of the wheel path. Rutting 19mm or less.
	6	No cracking. rutting 20mm or greater.
	7	Cracking confined to a single crack or extending over less than half of the width of the wheel path. Rutting 20mm or greater.
	8	Interconnected multiple cracking extending over the greater part of the width of the wheel path. Rutting 20mm or greater.

3.2.2 Present Service-ability Index (PSI): One of the major contributions of the AASHTO Road test was the development of a rating system involving the measurement of permanent deformation, riding quality and the extent of cracking and patching. This rating is probably the most widely used pavement rating measure in existence today. The rating goes from 0 to 5, 0 to 1 was very poor and 4 to 5 was very good.



Level of Servicibility for a Toll Road



Now a days 2.5 is considered critical and 1.5 as unfit to carry traffic. Functions of serviceability are, rutting, cracking and roughness which includes permanent deformation, transient deflection and curvature. The individual measurements of all these are combined to single index which is called PSI.

The value of PSI for rigid and flexible pavement is calculated by the following equations. For rigid pavement:-

PSI = 5.41-1.80 log (1+SV)-0.09(C+P).

For flexible pavement:-

PSI = 5.03 - 1.91 log (1+SV) - 0.01 (C+P) - 1.38 RD where:

PSI = Present serviceability index

SV = Mean slope variance

RD = Rut depth under 1.2 m straight edge

C = Linear feet of major cracking for 1000 ft area.

P = Bituminous patching in ft per 1000 ft area.

3.2.3 Roughness Measurement: The riding quality of a pavement is determined to a large extent by its structural adequacy, the traffic load repetitions it has been subjected to, the specifications adopted for the surfacing initially and the maintenance inputs. Hence a measure of the pavement performance can be obtained by monitoring its roughness. Although it has some limitations, probably the best method currently available for carrying out road ranking surveys is by measuring riding quality (roughness). There are two principal reasons for this. The concept of present serviceability index (PSI) parameter was used to rank roads on a scale of one to five. Analysis showed that PSI was related to the parameters of slope variance (roughness), rutting and the amount of cracking and patching on the road. However, it was noted that around ninety percent of the variability in the value of PSI was accounted for by the variability in the value of roughness.

Studies have shown that the main parameter that links road condition with vehicle operating costs is that of roughness thus roughness is the principal parameter that should be measured when determining the economic effect of road maintenance.

3.2.4 Deflection Measurement An evaluation of the structural performance of flexible pavements can be obtained by deflection method i.e. by Benkelman beam, by

Deflectograph etc. Pavement section which have been subjected to traffic deforms elastically under a load. The elastic deflection depends upon various factors, such as :

1. Subgrade soil type
2. Moisture Content and compaction of subgrade soil
3. Pavement thickness, composition, quality and condition
4. Drainage condition
5. Pavement surface temperature
6. Wheel load

Deflection is the most commonly used method of rapid ranking. It is possible to make rapid measurements by using equipment such as the Deflectograph, falling weight deflectometer etc. However such ranking only give guide to the structural condition of the road and to the strengthening requirements. They do not provide any guidance on the maintenance requirements in terms of the needs for recurrent and periodic works. Indeed, the experimental evidence at the moment suggests that, for roads within bituminous layers in the tropics, the use of deflection measurements combined with knowledge of cumulative standard axle loading is even insufficient to enable predictions about future strengthening requirements to be made. Deflection methods are also inappropriate for use on unpaved roads.

3.3 Pavement Deterioration Studies and Design Philosophies

The adequate maintenance requirements of a pavement and provision of strengthening overlay layers in time can be assessed only after careful research and data collection of highway deterioration. Such studies are now being increasingly felt necessary all over the world for the development of highway design models. The performance of selected pavements have to be monitored over long period of time, by periodic visual inspection and measurement of roughness, deflection, traffic volume and axle loads, CBR etc. Empirical relationships between the pavement distress parameters and simple properties of the pavement have been established. These equations enable the development of a pavement design system, where the maintenance needs and overlay requirements of a pavement can be predicted.

Apart from the use of instruments for measuring various types of distress there should be study giving attention to the development of a standardised visual rating system and its relationship with measurements of distress signs. For developing country like Pakistan, the need for simple techniques with out sophisticated instruments should not be over looked.

Roughness measurement should be recognised as the important data source for assessing maintenance needs. For this purpose, both the towed fifth wheel integrator and the car mounted units should be used.

Lastly, the opportunity of exposing the research scientists to the latest instrumentation techniques should be fully utilized. Though simple instruments such as the bankelman beam and bump integrator should serve the bulk of the research needs, more sophisticated instruments such as the dynaflect, laser-beam-based profile measuring devices, scrim, lacroix Deflectograph etc. should be introduced at least for research, though not for general use. To be more scientific highway maintenance studies should be more related to roughness measurements, crack and rut formation and skid resistance readings. More importantly, maintenance inputs are closely related to road user costs (safety, highway user time and vehicle operating costs) and thus an over all view of the transportation cost should not be missed.

3.4 Pavement Distress-Performance Relationship

As traffic loads, environment and other forces act upon the pavement system, the pavement responds with stress, strain deformation, fracture, polishing or wear. These responses to load and wear are termed behavior. Most of the analysis models currently used to design pavement structures are in fact, predictors of behavior. When the predicted behavior reaches a limiting value, distress is initiated. With time various types of distress develop and interact, and the resulting accumulation of distress acts to counter the ability of the pavement to serve traffic. This serviceability loss can occur as a result of the accumulation of a single type of distress or as a combination of several types. Certain types of distress such as single crack, do not in themselves cause pavement failure. However as distress accumulates, they may combine with other types of distress such as deformation and disintegration to cause the serviceability index to drop below an acceptable level.

Primary distress include those which have a direct and immediate effect on serviceability/performance. Secondary distress are those which occur as a corollary of certain types of primary distresses. For example, the cracking of a pavement due to temperature variation is a primary distress. The crack it self may not reduce serviceability; however, entry of water into the crack may precipitate a weakening of the underlying materials which may produce permanent deformations that lead to a loss in serviceability. These deformations are a secondary distress.

In many situations, rutting is the first type of distress to be observed in a flexible pavement. During the first 2-3 years, it would not be unusual to measure average rut depth in the range of 3 mm to 6 mm. The cause of this early rutting is thought to be associated primarily with densification of the asphalt concrete or upper layers of the pavement structure. Some plastic flow may also occur.

Asphalt concrete can probably accommodate an average level of rutting of 1 cm without seriously increasing the potential for cracking, when rutting exceeds this amount, longitudinal cracking may occur along the edge of the rut. It was found in some studies that rut depth less than 5 mm have no effect on serviceability, and that rut depths of up to 1 cm show only slight correlation with serviceability loss.

With aging cracking increases, if rutting reaches 2 cm cracking could occur sooner. Rut forms channels in which Water can be stored and cracks provide a path for the water to enter the sub structure. The result would be an increase in the level of deflection, under traffic, with possible, pumping of unbound fines in the aggregate base.

3.5 Assessment of the need for strengthening

Pavements after being in service deteriorate due to a variety of factors. A part of such deterioration can be made good by patching and periodic renewals. When the extent of deterioration is beyond such simple maintenance solutions, the pavement needs an additional overlay. Strengthening with such an overlay will overcome the structural inadequacy caused by traffic that has used the pavement so far and will enable the strengthened pavement to with stand the expected traffic in the design period.

Because of the need to assess the relative priority of different highways for structural strengthening and also because it is more economical to strengthen while the original pavement still has the ability to function as a structural measure an objective measure of structural deficiency is required.

The usual technique used for the non destructive testing of a pavement is deflection under load. The advantages of using such a simply determined parameter are that :

1) In most cases the deflection is proportional to the applied loading, so allowing results obtained under one test conditions to be compared with an other.

2) It is good indicator of structural performance.

3) It is an exceedingly simple measurement to make and machines have been developed for the rapid measurement of deflection over considerable lengths of highways.

The disadvantages have been stated to be that :

1) Deflection may not be related to permanent deformation in the case of a deeply rutted pavement.

2) Deflection does not always vary progressively with pavement fatigue and may not give adequate advance warning of when strengthening is required.

3) It is strongly influenced by pavement type, climatic and sub grade conditions.

3.6 Flexible Pavement Strengthening by Overlays

A highway normally continue to carry traffic for many years after the termination of design life and it follows that some form of periodic strengthening must take place. The principal objectives of any road strengthening policy have been defined as :

(1) A minimisation of expenditure.

(2) Provision of a suitable level of safety.

(3) Production of a reasonable level of serviceability normally measured as riding comfort.

(4) Maximum or adequate load carrying capacity.

There must also be limited disruption to traffic, to adjacent land use and limited noise and air pollution during the strengthening process. It is difficult to maximise each of these objective so there must be a compromise. Expenditure, safety and serviceability are always important. Serviceability should maintain adequate levels of riding comfort and minimise vehicle operating costs over the design life of the pavement.

In many countries, it is the practice for strengthening to be carried out on a road way after much damage has been caused to the pavement and this damage is evident at the road surface. often, however, the road condition by this time has deteriorated to the extent that rebuilding of the whole (Full construction) or upper layers (partial construction) of the pavement is necessitated. In other instances, a concrete or (more usually) a bituminous overlay is provided; however because of the significance of the structural damage to the pavement, the thickness of overlay required is large. Either of these solutions is very expensive, and usually costs more than would the earlier application of a thinner overlay, e.g. before major surface deterioration is apparent and before the structural integrity of the pavement is seriously compromised.

It is important to plan to place an overlay on a pavement before it fails, e.g. when the pavement is deemed to be in a critical but not a failed condition. Critical imply that there may be many years of useful life left after the onset of critical conditions. When a pavement is deemed to have failed, it usually implies that all or part of the pavement structure has to be reconstructed.

3.7 Overlay Design for Flexible Pavements

An overlay design differs from design of new pavement in that in the former the strength of the existing pavement is to be evaluated, whereas in the later the strength of the sub grade on which the new pavement has to be constructed is evaluated.

Overlay designs involve the following steps :

1. Estimation of the traffic to be carried by the overlaid pavement.
2. Measurement and estimation of the strength of the existing pavement.
3. Determination of the thickness and type of the overlay.

The exact design of overlays by analytical methods is rather difficult. Most of the design methods are empirical. The estimation of future traffic is done on the lines of standard axle load. The factors considered before detail design is proceeded are:

a) The maximum thickness of overlay that can be accommodated by bridge structures.

b) The ease with which changes in overlay thickness can be made, having regard to the effect on the longitudinal profile and surface water drainage paths. The extent of damage is also a major factor. When an overlay is used, it is normally extended over all lanes of the carriageway and the hard shoulder, regardless of which lanes have deteriorated.

3.8 Pavement Testing Methods

1) **The Benkelman Beam Deflection:** This apparatus was developed in the United States of America by A.C. Benkelman. The Benkelmen beam is used to measure the deflection of the road surface as a loaded wheel passes over it. It is measured by the rotation of a long pivoted beam touching the road surface at the point where the deflection is required. The aluminum- alloy beam is sufficient cylinder to pass between the dual rear wheels of a load up truck. It is 3.66 m in length and is pivoted at a point of 2.44 m from the tip, giving a 1:2 length ratio. The pivot is carried on a frame made of aluminum angle supported by three adjustable feet. The frame also carries, a dial gauge arranged to measure the movement of the free end of the beam.

In general there are two methods of measuring the deflection. In the first method the probe arm of the beam is inserted between the dual tyre to a distance of about a = 1.37 m and initial dial reading is taken (A). The vehicle is then moved forward to atleast (b) (3.05 m) past the tip of the beam. while vehicle is being moved forward dial gauge is recorded (B) when the dual tyres have slightly passed the beam tip. Twice the difference between the initial reading and the load reading is the normal, deflection, equal to 2(B-A). Twice the value is used because of the leverage ratio.

In the second method, the probe is inserted between the tyres to a distance of about a = 0.46 m, a load reading taken as the wheels passed the probe (B) and a final reading taken with the load out of range of influence ©. Here twice the difference between the two readings is the rebound deflection = 2 (B-C).

In many countries, the method for the Benkelman beam test has been standardised in detail, including the dimensions of the apparatus, the reaction load, tyre pressure, speed and temperature measurement. The load applied by the dual rear wheels of the lorry is often specified (for example) in the United Kingdom it is 3.75 tons and Finland 4, California 4.09, Japan and the Netherlands 5 and Spain 6.5 tons. The specifications used by TRRL say that the tyre size should be 7.50 x 20 or 8.25 x 20, with a zig zag pattern. The inflation pressure should be 590 KN/m and the spacing between the tyre wall approximately 45 mm. Since deflection is affected by pavement temperature, the measurement is made at a depth of 40 mm preferably when the road temperature is close to 20°C.

2) Traveling Deflectograph Defection: Measuring Deflection with Benkelman beam is relatively simple and slow piece of work, and only a very limited length of highway can be surveyed in one working day. In addition, carrying out the test can result in considerable traffic disruption. Traveling Deflectograph is more mechanised method for measuring Deflection. The Deflectograph travels at a constant speed of 1.5 km/hr whereas the reference frame moves discontinuously. During the measurement the reference frame stands on the road on four wheels and is completely independent of the semi-trailer. Measurements are done in both tracks every 11 m (usually at 39 KN wheel load but 64 KN is possible) and the total influence line is recorded digitally on magnetic tape.

The Deflectograph consists of a truck with a deflection beam assembly located beneath and am associated recording system. The beam assembly rests on the road, suitably aligned between the front and rear axle of the vehicle, and deflections are measured as the rear wheel assemblies each, loaded to 3175 kg approach the tips of the beams, which during this period are at rest in contact with the road surface. As soon as the maximum deflection has been recorded by electrical transducers located near the beam pivots, the beam assembly is pulled forward at approximately twice the speed of the vehicle by an electro magnetic clutch and winch system, to the initial position ready for the next cycle. An arrangement of guides ensures that the beam are aimed at the centre of the space between the rear twin tyres, even when the vehicle is negotiating bends. The working speed of the Deflectograph is about 2 Km/hr and the points of measurement are about 3.8 m apart on the road.

3) **The Dynamic Cone Penetrometer:** This is a very simple instrument used for measuring pavement strength. One man holds the handle at the top, while another person pull the sliding weight to the top (should not touch the top handle) and then allow it to drop. A third person is needed to record the reading in mm on the staff. Readings usually made after every fifth blow of the hammer. Readings should be made to a depth of 700-800 mm, after which the DCP is extracted by upward blows of the hammer on the top handle. The time for each test is 5-10 minutes depending on the strength of the pavement layers.

If there is no penetration after 10 consecutive blows the test should be stopped to avoid damage to the point of the cone. If the road has an asphalt surface of more than 20 mm thickness, a small hole should be first made through the asphalt course with a hammer and chisel.

The dynamic cone penetro meter is supplied a standard 1 m staff. The reading can be more conveniently made if the cursor is mounted on the top handle and an extension bolted to the staff. This also reduces the risk of damage to the cursor which tends to suffer fatigue failure from the action of the hammer when mounted on the anvil. For interpretation of results a plot is made of penetration against cumulative blows making a series of straight lines. Each straight line identifies a homogeneous pavement layer. For each layer the thickness (in mm) and the DCP no (in mm/blow) is extracted. Then thickness and strength are plotted to form a visual representation of the state of the pavement. By field testing a calibration can be made between DCP strength and insitu CBR and hence pavement layer strength co-efficient as used in pavement structural number which is an input to the HDM model.

CHAPTER IV

MAINTENANCE IMPLEMENTATION

4.1 Management and Work Programme Planning

The data required for the efficient operation of the highway maintenance system should include, for each basic activity:-

- The nature of the activity.
- The geographical identification of the maintenance site such as administrative unit, road number, site co-ordinates.
- Amount of work required in relation to quality standards.
- Resources used.
  * Equipment-hours by type.
  * Nature and quality of materials.
  * Man-hours by type (labour, foreman, driver, etc.)

These data are used to establish a work programme, i.e. a budget estimate by basic activity. The estimates can be worked out by road section work force and equipment can be approximately allocated. During the execution of the work, comparison between accomplishment and estimate will have to be made continuously at management control level proper, in particular with regard to quantity and performance standards. Differences will have to be explained and, when required, adjusted.

Series of activities in Maintenance Management Planning

Economic Appraisal

Assessment of serviceability level required for each route to give optimum return to the national economy.

Maintenance Management.

Data Collection, Screening, Selection of treatment, prioritisation and Costing.

Maintenance Works

Organising direct labour for contract, Effecting work in a correct manner.

Cost Control

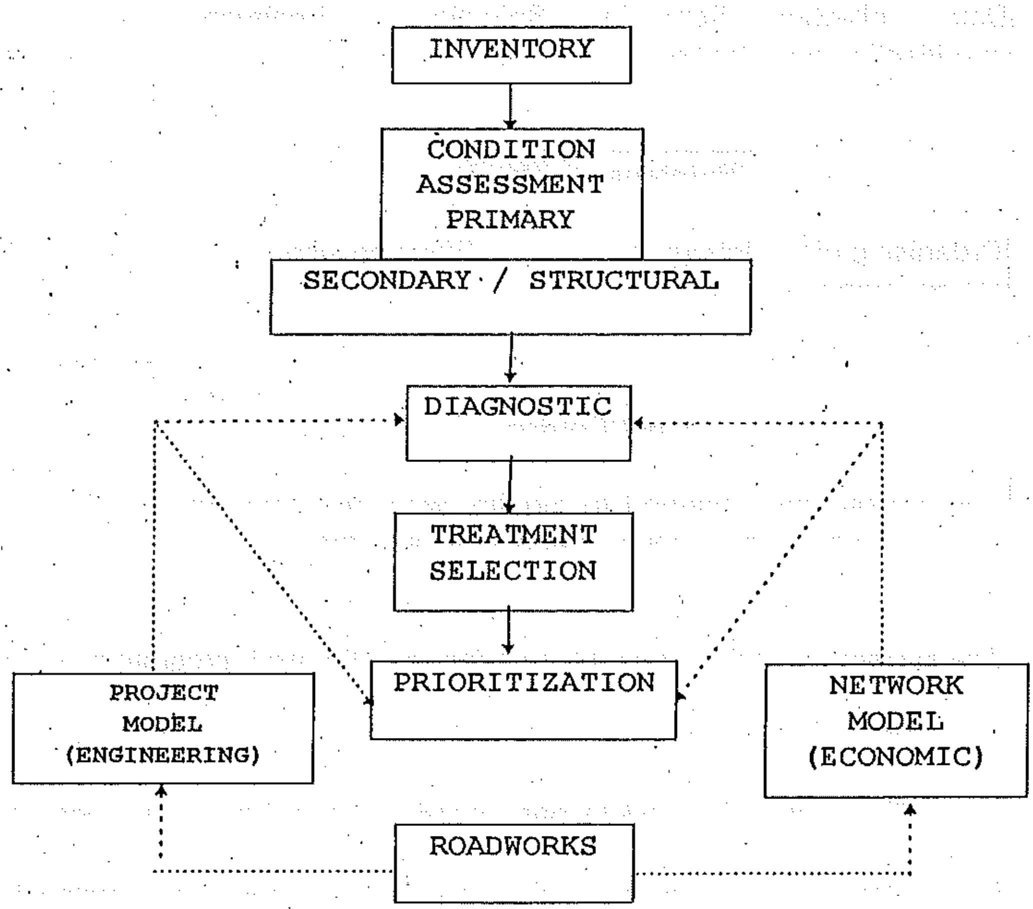
Cost accountancy method to monitor work and improve unit costs values and inputs to economic appraisal.

The system will make it possible to administer the work programme of the following year on the basis of past management data such as:

- **i)** Total cost of the work by basic activity, administrative unit, road, etc.;
- **ii)** Break down of cost into components: Labour, equipment, materials;
- **iii)** Ratios such as;
    - Hectares of mowing/year, depending on technique used.
    - liters of binder per meter of pavement, etc.

In addition, data will be available on equipment failures, their frequency and cause, and on the inadequacy, in quantity or quality, of the work force. The manager will obtain a very complete picture of the performance of his work forces and will have sufficient data to assist in determining whether corrective action or a change in plan is necessary.

4.2 Planning of Maintenance Operations



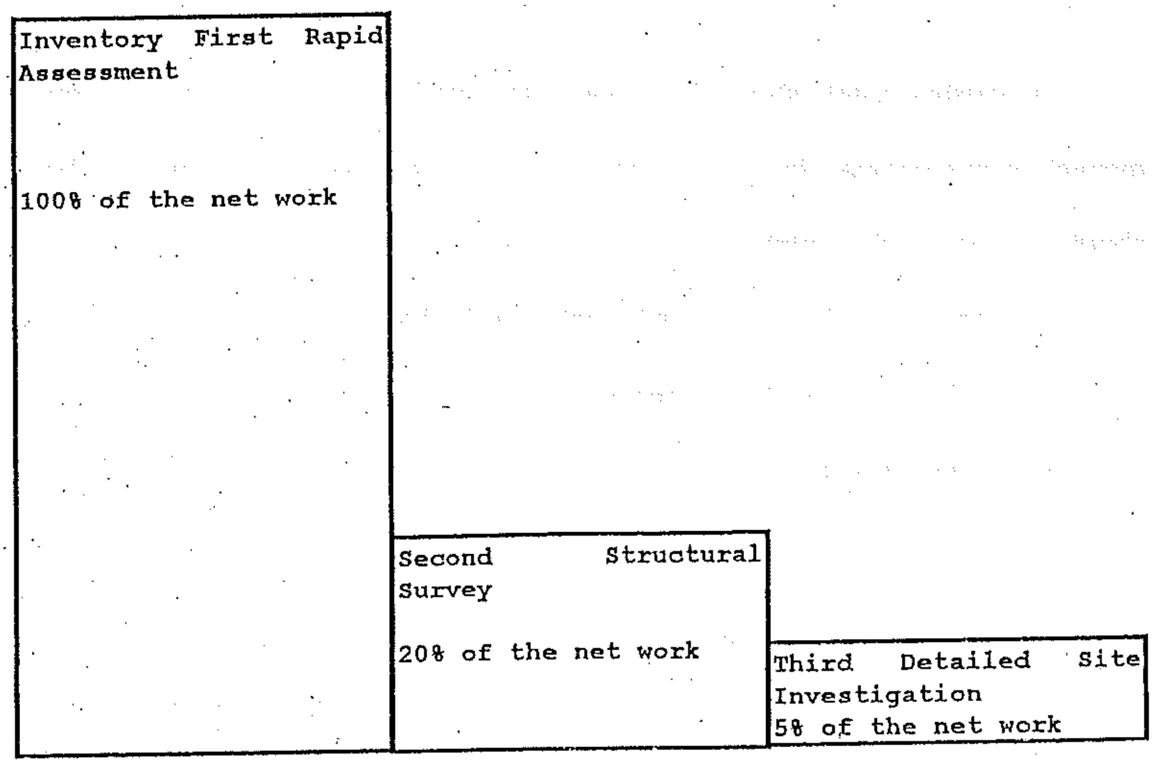
An idealized maintenance management system.

The first step to planning of maintenance operation is the evaluation of the existing pavement in terms of its physical condition, structural capacity, roughness etc. For this purpose, condition surveys based on visual assessment should preferably be conducted for each stretch of road twice a year, one before and the other after the monsoon. The data collected should be recorded methodically kilometer wise.

Based on the condition evaluation, the causes for the various defects should be examined in detail and decision taken whether to initiate a particular maintenance activity, defer the same or to go in for more detailed investigations. Any defect like pot holes should be rectified straight away. For other defects needing seal coat or renewals, the optimal strategy should be worked out having regard to the various factors involved including available finances. By this way, the maintenance operations should be planned as a total system.

4.3 Strategy for Maintenance

Most of the distress features of the pavements are common. In almost all cases it is possible to avoid or atleast contain the damage by carrying out systematic, continuous and a planned maintenance work. This is where the need for a strategy for maintenance comes into picture.



We can not go for every type of network in a similar way. By adopting a policy of stage condition survey every year the whole network is covered by rapid and cheap survey. Manual teams or machines can be used, no matter the way of data collection but important thing is to know the problem place. Cheap rapid first survey for entire network, second structural survey for 20% of the network, third detailed investigation may be for 5% of the network. We have two levels of maintenance management system as below:.

(I) Project level maintenance management system.

Road Condition-[Engineering-Local/District/Engineer]-Decisions-Projected/Rd/Condition-Actual Condition

(ii) Network Level maintenance management system.

Budget-[Eco.-Aid Agency/Policy/Committee/Treasury]-Decisions-Projected/Rd/Condition-Actual Condition

It is a known fact that the extent of maintenance efforts needed depend on the standard to which a road has been originally built. For example, a thin weak pavement built at a lower initial cost with inadequate drainage measures particularly in heavy rainfall areas involves a high degree of maintenance effort as compared to a relatively strong pavement. A probable strategy for maintenance may be as discussed below.

All existing roads should be properly inventorised, section by section and all data maintained in a compact form which may be called a road register or road data bank, which should be periodically updated.

The data bank shall contain information regarding :

a) Pavement width, carriageway width, shoulder, crust, thickness, type etc.

b) Whether fill or cut section, height of fill or cutting.

c) Nature of terrain, whether water logged etc.

d) Longitudinal and cross profile.

e) Pavement roughness and riding quality of surface.

f) Importance, category and class of road.

g) Visual condition for cracking, patching, rutting, other distress, conditions to be rated on a graded scale.

h) Structural conditions.

i) Drainage condition.

j) Environmental conditions.

k) Original construction cost.

l) Annual maintenance cost year wise after opening to traffic.

m) Type of maintenance measures undertaken (section by section details).

n) Traffic intensity.

o) Any other relevant data.

This type of road data bank should be opened in respect of new roads to be constructed with the relevant information to be added subsequently regarding its service condition after commissioning to traffic. Properly equipped mobile labour gangs with mechanism for quick action to attend to the maintenance operations as required should be organised.

4.4 Organisation of Work in the Maintenance Department

The organisation of work within a maintenance department is affected by fundamental decisions such as (a) The use of direct labour or contractors and (b) equipment based or labour intensive maintenance methods. Labour intensive methods have the advantage that they depend mostly on local resources; thus they generate useful employment that can be part time and can be phased to complement agricultural activities. Effective functioning is critically dependent on the provision of adequate incentives for efficiency and on good supervision through frequent field inspections.

Advantages of Equipment	**Disadvantages of Equipment**
1. Speed of Work	1. Creates few jobs
2. Good Quality	2. Uses Foreign Exchange
3. Cheap	3. Needs Skilled Operators
4. Convenient to use	4. Difficulty to Obtain Spare Parts
5. Ease of obtaining Finance	5. Needs Workshops and Skilled Mechanics
6. Well understood by Engineers	6. Problems of Transport in Remote Areas
Disadvantages of Labour	**Advantages of Labour**
1. Slow	1. Uses little foreign exchange
2. Poor Quality	2. Creates jobs
3. Costly	3. Requires few skilled operators
4. Labour Problems	4. Self-reliance
5. High Level of Supervision required.	5. Local manufacture development
6. Needs different management skills	6. Develops rural economy by putting money in hands of local people
7. Draws off workers from agriculture	7. Can be used on many sites concurrently
8. Needs different management skills	
9. Payment problems	

The organisational structure and management methods used within a maintenance department should be such that they result in the delegation of authority and responsibility to the lowest possible level.

This should result in a much more efficient organisation and will reduce considerably duplication of work by senior staff. The level of delegation should be limited only by the availability of trained staff and the minimum size of working unit that is viable. Routine and recurrent maintenance operations and management should normally be decentralised as much as possible and the maintenance engineer must ensure that the location and deployment of his crews is best arranged to meet maintenance requirements. The criterion for success should be the quality and quantity of work actually completed. This can only be assessed properly by field visits and inspections by supervisory staff, including senior staff from head quarters.

4.5 The Staffing Dimension and Training

In developing countries, the most serious constraint on highway maintenance is the lack of adequately trained or experienced staff. Also in government organisations the interest in maintenance is low and salaries are poor. The management of maintenance at all levels requires appropriate skills which can only be developed by proper training. The provision of well designed courses on road maintenance and management is necessary in all road maintenance organisations.

Maintenance training programme sometimes suffers from the over optimism of governments or their consultants as to the numbers of people that could be made available for training or to the educational back grounds that trainees or counter parts would have. In some instances training is directed exclusively toward the particular needs of two or three new mechanized units, to the neglect of the consequences for the remainder of the maintenance operation from skimming off the best personnel for such units.

A serious training programme for a maintenance organisation should be based on a careful, forward looking analysis of the prospective balance between the skills expected to be required, at different levels and in different specialties, and those that are already available.

Allowance should be made for considerations such as the learning capacities of existing staff, their availability for training, the need to replace expatriate employees, and the losses of staff that come about because government agencies are sometimes training grounds for the private sector. The programme should be comprehensive in the personnel that it covers from senior engineers and managers to patrol, man and drivers (of the Highway Department and any other entities responsible for maintenance, such as local councils), and in the modes of training that are considered, including overseas school and visits, counterpart arrangements, equipment supplier, courses, class room training, and on the job training.

From the long-term point of view, staff members need to feel that good performance during and after training will be appropriately rewarded in salary and status. Motivation of trainees is a key factor in successful training. It is partly a question of attitude and thus heavily dependent on appropriate leadership in the Highway Department.

4.6 The Institutional Set up

The institutional issue is above all a matter of moving in the right direction, toward an organisational structure through which the available resources will be applied most effective to the tasks to be accomplished. The first institutional question for countries to ask them selves and that has probably not often been answered thoroughly enough, is how much of the work on its highway, it is desirable to do in house, by force account, rather than by contract. The answer to this question deeply affects the nature and size of the government organizational structure that will be required. Many maintenance forces find themselves heavily diverted in practice to construction and improvement that might better be left to contractors.

The use of contractor can reduce the burden on scare government staff and can also reduce costs, as a result of competitive pressure to efficiency that are difficult to duplicate under civil-service arrangements. An even flow of relatively small jobs, such as regravelling and resealing, more over is an ideal way of fostering a nascent domestic contracting industry. Ways have been found to write a fair and acceptable contract, even for routine maintenance; essentially it consists of evaluating and specifying the aggregate amount of work in each category to be done per kilometer a year on each given section of road, with emergency repairs to be paid for at tabulated unit prices.

At the opposite end of the technological spectrum, labour-intensive methods can often be used economically, routine maintenance, particularly in densely populated areas where laborers who live near the road can be employed without the necessity of providing costly transport.

For network, another institutional responsibility that must be clearly provided is axle loading control. The setting of axle load limits is generally the responsibility of the ministry concerned or some similar body, while enforcement and operation of vehicle weighing stations may be in the hands of its officials.

What the experience of extensive failure and difficulties of enforcement of local limits shows above all is that the establishment & introduction of appropriate limits need to be done in close cooperation with association of Truckers & within the broader frame work of regulation of the tucking industry.

4.7 Financial Constraints

Separate funds for maintenance purpose either not allocated or have been diverted to non-maintenance projects. This problem causes a serious backlog of maintenance. Another problem in highway maintenance is to ensure that available funds are actually spent. If yes are these spent steadily and effectively. Experience has shown that obstacles exist at every level. They may come, for example, from political concern that public opinion will be more impressed with new works; from the reluctance of planners to cut budget for capital development and preference for schemes with a sharp development effect.

The revenues from road users i.e. gasoline and diesel taxes license and registration fees, import and excise, taxes on vehicle and components, and toll and fines are multiple of maintenance needs. Revenues from this industry can be more than all public highway expenditures, including construction.

Country	Maintenance %age out of total funds
Pakistan	10
India	20
Sri Lanka	20
African States	20
Developed countries	60-70

Source- Seminar on management and financing of roads maintenance by ESCAP and World bank (Bangkok September 1996).

Some countries have sought to resolve this dilemma by earmarking certain taxes for use on highways, which fully covers the cost of routine and periodic maintenance.

In many developing countries a separate account have been set up to receive all or part of field revenues. Usable only by the department and only for maintenance operations.

An appropriate way of managing highway network is creation of a financially self sufficient, semi public national highway authority.

Even if an independent authority is not created the commercial notion that country's highways are fixed assets, for whose maintenance it is reasonable to pay a few percent of replacement value annually, is helpful in promoting the cause of maintenance.

Since inadequate maintenance is neither good engineering nor-good economy, we should make concerted efforts towards enhancement of funds to appropriate levels. These efforts can be more effective if the various implications of inadequate or delayed maintenance can be brought out in financial as well as operational terms. There have been cases where release of road maintenance funds becomes belated, leaving little room for planning and preparation. Similar situation results also when the funds undergo large variation from year to year or cuts within a year. The need is that road maintenance should be accorded a higher priority then new construction, and there should be major policy shift in favour of road maintenance both in terms of financial allocation and organisational efforts.

4.8 Road user charges and expenditures. (NTRC's Study 1987). In Pakistan, the revenues from road user charges are put in the general budget of the central government and provincial/local ones, not specially designated to expenditures for roads. However, a study "Road User Charges in Pakistan" was conducted in 1986-87 by NTRC to compare revenues (government incomes)and expenditures related to roads of the country. The study indicates "the taxes paid by road users were more than the expenditures on roads in 1984-85. If the all revenues through taxes are allocated to the expenditures, the expenditures can be expanded by 90% in that year.

Revenue and expenditures of roads, 1984-85(Rs. million)

Sector	Tax Revenue from fuel and Vehicles	Expenditures on Roads
Federal	6615	1010
Provincial	904	2189
Local	102	1014
Total	7621	4213
exp/rev	100	55

Source- Road user charges in Pakistan (NTRC, 1987)

Revenue and Expenditure in 7th FYP (Rs million)

Sector	1988-89	1989-90	1990-91	1991-92	1992-93	Total
Revenue	15147	16830	20950	22412	27145	102484
Expenditure	6323	7438	8313	15299	20388	57761
Ratio R/E	42%	44%	40%	68%	75%	56%

Source- NTP by JICA 1995

Revenue and Expenditure in 8th FYP (Rs million)

Sector	1993-94	1994-95	1995-96	1996-97	1997-98	Total
Revenue	35868	35868	37661	37661	39534	186592
Expenditure	23651	23651	24125	24125	24622	120174

Source-NTP by JICA 1995

4.9 Role of Consultants in Maintenance

Traditional consultant functions, such as preparation of bid documents, evaluation of bids and contract supervision, are only a minor part of the contribution needed from consultants in most maintenance programme. Layout of alternative organizational arrangements and implementation of the client's chosen arrangements, advice on procedure and systems, training on the job and in courses and seminars, preparations of manuals, institutions building in the broadest sense are the main jobs for which consultants are called upon in maintenance.

The task is more complex because human considerations are often more important than technical ones. Foreign consultants and technical assistance under increasingly precise terms of reference have been heavily involved in preparation and execution of almost all the significant efforts to improve maintenance that have been undertaken with assistance from the World Bank. While consultants have often been overoptimistic about what they would be able to accomplish, they have generally made a vital contribution to what was done, a contribution recognized by both the borrower and the bank in the form of the contract extensions that have characterized the large majority of maintenance projects.

One of the most difficult problems in guiding and managing consultants is to set the right balance in their work between preparation of manuals and systems. For accounting, estimating, counting traffic, and so on and actual training of personnel. In many instances too much attention is given to preparation of systems and insufficient attention to training and human contact. Some teams of consultants have too much management expertise and insufficient field experience, and most have too little training expertise. Foreign technical assistance needs to be neither accepted too readily nor resisted too strongly. The absorptive capacity of a maintenance programme for technical assistance can increase in time, as the size of the local staff increases and any initial reluctance to take advantage of the assistance of expatriates is overcome.

CHAPTER 5

ASPECTS OF MAINTENANCE

5.1 Quality Standards for Maintenance

First and fore most approach is the aspect of specification of minimum acceptable level of serviceability for different categories of roads. Below these minimum acceptable serviceability levels adequate maintenance measure are to be taken to ensure the basic minimum requirement at any point of time during the design life of the road. The objective in measurement of serviceability during AASHTO Road test was developed to simulate user's subjective evaluations of the riding quality provided by the pavement. Pavement serviceability or riding quality is largely a function of pavement roughness. Studies made at the AASHTO Road Test have shown that about 95 per cent of the information about the serviceability of a pavement is contributed by the roughness of its surface profile.

In general the concept of maintenance programme is to out line and define the effects of a given road condition on road users, but the problem is to define at what point a given activity should be carried out in order to correct a defect. Economic analysis cannot replace quality standards and is practically ineffective when deciding upon the need for a certain maintenance action. Once the decision to take action has been made, it can however be complementary to quality standards and carefully play its role in defining the means for action and deciding upon the basic activity to be carried out. The purpose of quality standard is to remedy this short coming.

Quality standards should be based on measurable criteria. That can be established by systematic study of the condition of the road. As far as possible quality standards providing for frequency of maintenance that do not fit the actual needs should be avoided. Quality Standards should also take into account traffic and climatic factors which are important when establishing priorities. The best way would be to establish a system of standards for each class of traffic considered when setting up the general policy. The problem of evolving significantly improved standards requires a fundamental change from subjective to objective considerations. To do this requires a good deal of medium to long term research. The basic requirement should be to balance the cost of carrying out certain maintenance operations against the benefits gained when the work is done, or the penalties incurred when it is not done. It is important to ensure that a road gives maximum comfort and safety to the road traffic. The best possible riding surface should be thus saving on wear and tear of vehicles and energy costs. For this purpose, in order to decide the type of maintenance and rectification measures to be undertaken it is necessary to assess the degree of surface finish or the riding quality of road.

5.2 Collection and Analysis of Riding Quality Data

Collection and availability of data is always under-estimated and this is significant given the need to plan maintenance activities on current information. Frequently little or no data existed, and a specific resource had to be directed to their collection. It is more trouble some to collect certain data that at least in theory is available through existing channels. Sometimes there is wrong kind of data, and frequently it takes time to disentangle what is required from what had been collected. It is always difficult to do this with historic data, and it is not always possible to check with the person or organization responsible for their collection. On the basis of surface finish or the riding quality of the road, an evaluation of the serviceability of the pavement and stage for repair or up grading and measure to be undertaken for the various stretches decided.

For collection and analysis of riding quality data the road network may be divided into several sectors, depending upon the availability of equipment, trained personal and the operational convenience. Based on visual aspect and history of maintenance the road lengths may be divided into two broad groups. Group 'A' are roads which would require major strengthening works to restore desired performance levels and Group 'B' are roads which may not require any major strengthening or up grading measures in near future. This grouping will reduce the preliminary assessment work considerably and would enable the detailed testing work for up grading to be taken up much earlier. Group 'A' is expected to include roads that will have performance level corresponding to poor and bad as per the adopted riding quality criteria. Group 'B' roads are to include roads with performance levels corresponding to fair to good. Influence of personal factors, in general will be restricted to the border line cases.

The information will be of considerable importance in analysing performance of various constructions and the effect of different influencing factors and would help in formulating riding quality standards. Procedure to be adopted for the determination of the un evenness of the roads shall be as per the standard procedure out lined by the TRRL using vehicle towed device.

The quantified roughness values as how ever do not distinguish between large numbers of small undulations and small numbers of large undulations.

5.3 Road Monitoring

The object monitoring is to ensure that resources are being used as introduce and their use is achieving desired results. Monitoring serves two main purposes: It enables the maintenance engineer to check the quality and effectiveness of the work being done. It provides data that can be used to improve the management and performance of future maintenance operations. The engineer subordinate is required to compare the actual out put of the road gangs with the periodic work assigned by him at the end of every period.

This review includes a comparison of quality and amount of work achieved relative to that planned in advance after holding discussions with the road gang. The causes of short fall should be noted against each item. The results of the review help in planning further work. In some cases the short comings have been observed to arise from causes beyond the immediate control of maintenance staff, but it helps in identifying problems which can not be overcome immediately and also to avoid setting impractical targets for future work.

The task of monitoring covers two main aspects :

(1) **Site Inspection** This needs personal involvement of maintenance engineer in the inspection process. He should use vehicle driven slowly along the section being examined. Some part must be inspected on foot. He should examine closely the road surface. Side drains, culverts and soil. It is best if he travels as a passenger: he can then concentrate on his inspection, and when he goes off to look at the road his driver can follow with the vehicle.

(2) **Desk Review**This is another important task which involves reviewing all maintenance documentation i.e. inspection reports, resource requirement

forms, work schedules and completed work sheets. So as to assess the performance of the programme and the effectiveness of the management system. It provides an opportunity to check that adequate resources were allocated to each task and that maintenance problems were treated efficiently; cost estimates can be compared with expenditure and production targets with output and the reason for inconsistencies or short falls can be identified. In some cases, resources may have been in- sufficient in other words targets may have been pitched too high.

5.4 Trend in Road Maintenance in Developing Countries

By force of circumstances, road maintenance is becoming fashionable. An area which until recently was unglamorous and boring has suddenly taken on a more attractive aspect. Is this because engineers and politicians have suddenly realised the intrinsic merit of road maintenance; have they all of a sudden recognised the need to utilize government funds to safe guard investments? Hardly! It is more a question that many governments are having to face the fact that the road network is breaking up at a faster rate than it is being added to. That the money spent on construction is often money wasted because there are insufficient funds available to maintain the roads.

Aid donors have attempted to solve the problem by putting money into more equipment and training and to provide some form of planning and control management system. This has effectively avoided the major issue which is that government in general have to finance maintenance from their own resources. The basic problem is that most developing countries do not have nor will have in the foreseeable future - sufficient local resources to effectively maintain the network. We are all aware that much of the money allocated is not very effectively utilized. Large proportion of the budget are expended on a permanent labour force which is paid whether they are maintaining roads or not.

Moreover it should be recognised that maintenance expenditure figures do not provide any indication of maintenance quality. The evidence suggests that large part of maintenance expenditure is lost in overheads or in badly executed work.

Further, actual maintenance expenditures are generally made on the primary network. Thus not only is the actual maintenance expenditure insufficient for the needs of the network, it is only used to maintain a relatively small amount (in length) of the network. The fact that most of the maintenance expenditure goes on the primary road network should not be surprising because:

a) Those who travel on the primary network are often those who are in the best position to apply pressure for better maintenance; by and large those traveling on the earth roads are not powerful members of the society.

b) The calculable economic returns are much greater for the maintenance of paved roads (major roads).

c) Donor agencies provide training and equipment for primary road maintenance.

The problem described above are very real and, indeed it would be unrealistic to suggest that they can be easily solved.

5.5 Factors Influencing the Type and Quantum of Maintenance

There are several factors which affect the extent of distress and consequently the maintenance effort, these include, the original design, the composition and intensity of traffic, type of climate and terrain, type of surfacing provided. The organisational infrastructure, appropriate technology, availability of funds etc.

Discussing these factors individually, the original design must satisfy certain functions i.e. it should be sound enough to withstand stresses, it should be sufficient thick to distribute the loads and stresses to subgrade. The wearing surface should have reasonable strength, with good riding quality, the surface should be impervious so that water does not get into the lower layers of the pavement and the subgrade and cause deterioration. If the pavement has long life the cost of maintaining it annually would be low.

Traffic composition has a vital role in pavement deterioration and other maintenance related considerations. In this country the traffic is heterogeneous in character, consisting of fast driven cars, trucks, buses, coaches and slow animal drawn vehicles. Also the intensity of traffic indicate the service/quality for which the high way is being planned and directly affect the features required for frequency of maintenance.

Climate and terrain conditions also affect the maintenance effort, when the soil is soaked with rain water sub grade becomes weak resulting poor withstand to super structure load this causes early failure and distress. Mountainous and desert roads are more difficult to maintain due to land sliding and storm.

Types of surfacing is also an important factor in maintenance process as gravel and earth roads require frequent. Maintenance attention for filling up the ruts and leveling. The paved surfaces treated in single or more layers also get rapid deterioration when disintegration of surface dressed road Take Place.

Success of any programme or work heavily hinges on the organisational machinery and how it is geared to meet the challenges, the maintenances of roads in no exception. Proper organisation of labour into viable gangs with necessary complement of hand tools and equipment is essential for smooth and effective execution of the maintenance operations.

It is highly desirable from social angle that the development process should benefit every one through employment generation, equitable income distribution and social welfare. The labour based methods are attractive from employment generation angle. At the same time the use of equipment is important for maintenance of proper quality standards. A mix of labour and equipment can make it possible to get better results.

The gap between what we can achieve with need based strategy and resource based strategy must be quantified in physical terms, road by road and should then be documented and reported back to the policy makers together with a broad economic analysis of the repercussions it would have on the over all development.

5.6 New Direction in Road Maintenance

Just like other structures once a road is built it has to be maintained. Falling government revenues over the last decade have meant that governments have had to try and save money where ever possible and because the results of insufficient road maintenance do not become obvious for some years, road maintenance has been one of the first areas to suffer in the developed world, cuts in road maintenance have generally not been so severe that roads have been lost, but in the developing world, where money and other resources for even the most essential maintenance have been in short supply, the situation has become much more serious, particularly in recent years. In the developing world generally, it is estimated that over a quarter of the road network now needs partial or total reconstruction. In an effort to reverse the trend of deteriorating roads in the developing countries, bilateral and international aid agencies are now switching their funds for roads away from new construction and into building up maintenance capabilities. It has not been easy to bring about this change in aid policy. Politician in the developing world have favored prestige road building projects giving a facade of development, rather than the sort of long term institution building which is a primary feature of maintenance projects. Donors also have pushed new construction seeing it as a better advertisement for their aid and a better market for their products, then road maintenance.

The result has been that in a number of countries, the Governments have been left with an increased length of many highways which the over burdened local maintenance organisations cannot maintain because funds have not been increased and because new roads have been constructed according to unfamiliar technologies. Even Technical Staff in roads departments have looked upon road maintenance as a thoroughly unglamorous occupation, lacking in technical interest and best carried out by the less abled ambitious members of the organisation.

5.7 Technical Management Opportunities

The maintenance engineer now has an arsenal of highly sophisticated equipment which is able to monitor road and traffic condition rapidly and without affecting the movement of vehicles. These surveys cover factors such as pavement strength, skidding risks, road roughness, traffic counts and axle loadings, together with geometric, construction and cost data for the roads and accident records. The results are more than can be analysed manually, so the complete inventory of road network data is now usually kept on a computer, where it can be constantly updated, and from which it may be easily retrieved by maintenance planners.

To make full use of the mass of data now available, complex economic road deterioration models have been developed. By forecasting the probable effects of different maintenance strategies on pavement deterioration, and hence on the cost of operating vehicles over the road and comparing operating costs with maintenance costs. These models can point out the particular maintenance programme which will result in the minimum total transport costs for the network. Where funds for maintenance are limited, as they generally are, these computer models can identify the maintenance programme with in the available budget which will best preserve the road network with minimum total transport cost.

Moving road maintenance away from traditional rule of thumb, operation and into planning methods based on modern technology has placed the maintenance engineer in a much stronger position when it comes to allocation of funds. He has the evidence that a good standard road represents one of the best possible use of public funds, producing benefits for the community for higher than can be obtained from almost any other form of investment.

CHAPTER VI

MAINTENANCE PRACTICE BY NATIONAL HIGHWAY AUTHORITY

6.1 National Highways Network

The total length of National Highways is 6638 km (figures in 1996). The following is a list of the National Highways. Their routing and measured length.

Highway Serial No.		Name of Highway	Length-kms
1.	N-5	Karachi-Lahore-Peshawar-Torkham	1,762
2.	N-25	Karachi-Kalat-Quetta-Chaman	817
3.	N-35	Hasanabadal-Thakot-Khunjerab	806
4.	N-40	Lak Pass (Near Quetta)-Dalbandin-Kohi-Taftan	625
5.	N-50	D I Khan-Zhob-Quetta	531
6.	N-55	Kotri-Larkana-DI Khan-Bannu-Peshawar	1,265
7.	N-65	Rohri-Sibi-Quetta	385
8.	N-70	Qila Saifullah-Loralai-DG Khan-Multan	430

6.1.1 Major Characteristics of the Network

An outline description of these routes is as follows:

- N-5

The national route N-5 is by far the most important of all the highways and itself carries a high percentage of all traffic on the network. The kilometer marking on this route originates in Karachi making progress from South of North through Sind and Punjab provinces to North West Frontier Province and the Afghanistan border. The N-5 is 1,726 km in length.

- N-65

The national route N-65 originates at its junction with the N-5 at Sukkur and travels northwest from Sind Province to Baluchistan and finishes at the junction with N-25, a few kilometers from Quetta, the provincial capital of Baluchistan Province. The N-65 is 385 km in length.

- N-25

The national route N-25 also originates in Karachi progressing north through Bela, Khuzdar and Kalat to Quetta and from there further northwards to the Afghanistan border at Chaman. The N-25 is 817 km in length.

- N-40

National route N-40 originates at a junction with the N-25 at Quetta is Baluchistan and travels due west through the towns of Nushki, Dalbandin and Nokkundi to the Iranian border at Taftan. The N-40 is 625 km in length, with only a small section still to be paved.

- N-50

The national route N-50 originates in Quetta at the junction with the N-25 north of the city. The highway travels east through Muslimbagh and Zhob to Dera Ismail Khan. The N-50 is 531 km in length.

- N-35

National route N-35 originates in the southern part of North West Frontier Province (NWFP) at a junction with the N-5 approximately 50 km.west of Islamabad. It then travels directly north out of the province into the Northern Areas Agency. It travels through Thakot, Besham and Chilas to Gilgit at the heart of the Northern Areas. It then passes through the Hunza valley to Markhun and Diland and terminates at the Khunjerab Pass, which is Pakistan's border with the Peoples Republic of China. The section currently maintained by the NWFP is 190 km, although part of this has temporarily been allocated to the Frontier Works Organisation (F.W.O) who also maintain the 616 km from Thakot bridge to Khunjerab Pass. The total length is 806 km.

- N-55

National route N-55 originates is Sind near Hyderabad at a junction with the N-5. For the initial pat of its route traveling north to Dera Ghazi Khan, it travels through irrigated farmlands which causes the water table to be near ground level. From D G Khan to D I Khan, this section in the Punjab region has lengths that have been improved, and some sections needing attention. From D I Khan the N-55 moves onto the higher ground of North West Frontier Province and the problems are related to roads in mountainous areas. After leaving the Tribal Area of D I Khan, the busiest section of the road terminates in Peshawar City. The total length of the N-55 is 1,265 km.

- N-70

National route N-70 begins in Multan City and travels west through Muzzafargarh to D G Khan. This section of route is heavily trafficked. From D G Khan the road passes through the Tribal area of Fort Munro throughout the border with Baluchistan to Lorali and on westward to Qila Saifullah on the N-50 south of Zhob. The total length of the N-70 is 430 km.

6.2 Historical Development of National Highways Maintenance

6.2.1 Practice Before Establishment of NHB The National Highways Board was established in 1976 to take over the responsibility for the upkeep and maintenance of those major trunk roads, which were designated as National Highways. These major trunk roads had until then been the responsibility of individual provinces, but it was felt that the condition of these network was so important for the national development efforts, that it should come under direct control. However, each provincial government represented at the board, normally by the Secretary of its Communications and Works (C&W) Department, while its Chairman being the permanent Secretary of the Federal Ministry of Communications.

The reason for taking over the control of maintenance from provincial C&W Departments in 1987 being that the provincial direct labour organisations did not have the extra capacity to undertake the necessary new and accelerated standards of maintenance outputs that were required. Their own problems of an ever expanding provincial network and the demands of transport with their regions invalidate any over commitment on the national routes.

Before taking over by NHB the routine maintenance work on the National Highways was mainly carried by the Provincial C&W's on behalf of National Highway Board. For this purpose the C&W's used to use their present general field organizations, i.e. the C&W divisions, districts, subs division etc. which were responsible for all C&W activities within their areas, but were required to assign in the order of one labour per 3 km and one overseer per 15 kms, exclusively to attend to the National Highways traversing their areas.

In some provinces it was admitted that possibly upto 40% of the National Highways Board fund allocated was extracted "upfront' for payment of salaries, it is reasonable to believe that National Highway Board was not getting value for money from the C&W's and the low standard of maintenance generally observed supports this.

6.2.2 National Highway Board's Role National Highway Board was given the responsibility of improvement, maintenance and general management in mid 1980's. The Board had itself originally been created as the Indus Highway Board to management the major improvement programme of the Indus Highway. NHB was not generally organised in the provinces at that time to properly supervise and central maintenance activities undertaken by the C&W's by force account or contact as its agents. Consequently, the level of supervision was low, regular detailed inspections were not carried out and work scheduling and measuring of routine maintenance items were not part of the framework of organisation.

The pilot field organisation established by NHB in Sahiwal for its direct supervision and control of routine and periodic maintenance by contract of the Multan to Lahore Section was found promising and the method of maintenance seemed pointing in the right direction for maintenance of the National Highways. With the involvement of the World Bank in the National Highway Sector, the NHB concentrated on the management of improvement schemes being propagated under the various highway loan agreements. These schemes were almost totally confined to N-5. As a consequence, the maintenance aspect of the network was left almost entirely to direct labour departments of the regional authorities.

The NHB acted as the clearing house of the allocated funds which were paid to the provinces to cover maintenance costs. Within the Boards organisation at headquarters were Directors responsible for liaison with provincial authorities. They did not, however, had any field network or officers permanently acting as maintenance site engineers.

The principal members of the Board were the four Secretaries from the Provincial C&W Departments. The Board was led by the Secretary of Federal Ministry of Communications and he was assisted by the Director General of NHB. Decisions on policy concerning maintenance were generally speaking influenced primarily by the interests of the various provincial C&W Departments. Prior to practice started in 1987 the NHB's role in maintenance management was almost entirely liaison only.

6.3 The Maintenance Implementation Project

6.3.1 Formation of Maintenance Directorate The maintenance implementation programme was started by NHA in 1987 with certain objectives. The main component of the project was to establish the capability of managing a country-wide maintenance programme on the national network. As a complement to this prime component, there were the additional inputs for structural maintenance, construction, supervision and general staff training and awareness programmes.

The maintenance implementation programme began in October 1987 and was directly under the control of the Director General NHB. With the programme expanding to meet its objectives, it was clear that NHB had to create a maintenance directorate to handle the project's outputs. In 1988, the Board agreed to the formation of a Directorate, which was responsible for all the ongoing services and outputs of the consultants and the Director was responsible directly to the Director General.

Within the Directorate was created the Pavement Monitoring Unit (PMU). This consist of five members who remained working alongside the consultants. In 1991, another five members were appointed and the Unit was ultimately named the Project Engineering Unit (PEU).

6.3.2 Establishment of the NHB Field Office Network In 1987, thirteen field offices were set up in the country each office was headed by a Deputy Director of maintenance supported by Assistant Director and Inspector. The staffing levels were initially based approximately on the length of national highway under the jurisdiction of the office in question, their extension based on the measured work that could be foreseen in each maintenance year. A further three offices were established in 1988.

The maintenance management programme was given by the consultant in conjunction with the maintenance Directorate. The following main objectives and components were included in Implementation Contract with the Consultants in 1988.

Objectives - Implementation Contract

(a) Replace the yardstick system of budgeting with a unified system of measurements.

(b) Establish a two tier system of maintenance management for Routine and Periodic works.

(c) Introduce a Maintenance by Contract System.

(d) Establish within N.H.B. a Maintenance Directorate.

(e) Form a Pavement Monitoring Unit to expand the already introduced (in the Study) methods of measurement and defect analysis.

(f) To advise, assist and train maintenance contractors.

(g) To assist with the establishment of a Traffic Engineering Unit in N.H.B.

(h) To advise N.H.B. on the computerisation of all relevant items used in the maintenance management execution.

(i) Assist with pavement design for the perceived improvements programme in the first stages of M.B.R.P.

(j) Establish a structural assessment capability within the N.H.B. organisation capable of carrying out inspections, rating and basic design work for a Bridge Maintenance Management Programme.

(k) From the annual M.I.L. results, identify and evaluate the sections to be included in the M.B.R.P. scheme.

(l) Identify in conjunction with N.H.A. a three year programme of improvements to be included within the M.B.R.P. project.

(m) Establish the mechanisms for dealing with extraordinary activities in maintenance of the type envisaged for M.B.R.P.

(n) Establish contracting/supervision procedures for administering the M.B.R.P. scheme. All the foregoing are given in detail in Chapter 8.0 where the various objectives are directly related to the targets achieved.

6.3.3 Adoption of a Suitable Maintenance Intervention Model For the Maintenance Study in 1986, a version of H.D.M. III adapted for use on a PC was used to forecast the necessary maintenance programme and the required improvement overlays.

The findings from the Study, however, were far too radical in their financial requirements for full adoption by G.O.P. Only cost of living indexed types of increase could be considered by the M.O.C. and Ministry of Finance.

There was therefore a need to develop a simple straightforward way of prioritising those funds that were available.

In a similar situation, the Consultants had developed an easy-to-use highway maintenance rating system based upon the highway defect analogies developed and documented by the Transport Research Laboratory of the U.K.

The system was prepared to suit the conditions of Pakistan and a presentation made to the Board during its first meeting in 1988. It was accepted and after a further vetting by I.B.R.D. mission members, it was adopted. It was called the Maintenance Intervention Level System (M.I.L.).

6.4 The Maintenance Intervention Level (MIL) System

The Maintenance Intervention Levels are numerical ratings. These ratings are place upon a pavement defect and its severity. The defects and severity categories have all been developed by the Transport Research Laboratory in the United Kingdom based upon years of empirical research in many countries with many varied types of road condition. All the ratings are objective measurements and rule out disparities of what constitutes a maintenance problem.

To this physical assessment of the pavement condition is added an environmental rating which is based upon the local conditions of climate, traffic volumes and predominant geotechnical features such as C.B.R. of the predominant subgrade.

By building up an aggregated "score" for each 5 Km link of the network, it is possible to favorably compare one link to another (given the same starting parameters) and simply target the maintenance money according to the scores.

The range of scores applying to the National Highway network of Pakistan are as follows :

>70 This road needs reconstruction/rehabilitation. Only safety related maintenance should be carried out.

60-69 The road pavement is in need of improvement. Major periodic overlays should be programmed.

50-59 A road segment with this rating needs localised periodic maintenance.

40-49 This road segment needs routine maintenance. It should be given preferential status over other road maintenance.

<40 This section of road needs routine maintenance. It should be given attention only as budgets permit.

M.I.L. presents limitless opportunities for use. It can be used under a wide variety of conditions. The scoring parameters can be amended to suit the development of the network as interventions become effectiveness.

By analysing the M.I.L. scores over the network over a period of years, the highway authority can determine future policies with greater degrees of confidence.

The system proved to be easily absorbed by N.H.A. and has now been running with good effect for several years. The additional funding required for improvement overlays (the M.B.R.P./R.S.P.) programme as contained in the Transport Sector Loan Agreement No 3241 PAK signed in 1991 between G.O.P. and I.B.R.D. was based upon the justifications provided through the M.I.L. system in the three years previous to that date.

6.5 MIL Data Collection and its applications.

MIL works by taking simple, direct measurements of roadways and their environs. The entire highway network is divided into contiguous five kilometer sections. Measurements are taken along one representative kilometer of each five kilometer length over the total highway system. All the measurements are analysed in a central office where the specific maintenance needs of each road segment are ranked. each individual measurement is assignments a severity score. These scores are combined to obtain a total which indicates the level of maintenance needed by each roadway segment.

Scores are forwarded to maintenance field offices. Field engineers know the roads best. They use the scores to estimate the amount of materials that will be necessary to correct high priority roadway deficiencies. The cost of carrying out the programme is also estimated. This information is used to prepare a finalised work programme which matches the maintenance budget.

The key to MIL's success is the direct, simple, and comprehensive information used to determine the intervention level score. Eighteen distinct factors are measured or defined in order to determine a road's maintenance needs. These data are broadly grouped into two categories : a) conditions which may be improved by maintenance (e.g., the roughness of the road) and (b) factors which influence how much maintenance the road needs (e.g. climate, terrain, and levels of traffic). These yield a complete understanding of the road in a manner which allows technicians and laymen alike to understand MIL's results.

Information collected as part of the MIL analysis includes :

a) Road type

b) Road width

c) Pavement type

d) Pavement roughness

e) Number of potholes

f) Length and depth of rutting

g) Pavement cracking

h) Axle Loading

i) Pavement and subgrade strength

j) Rainfall

k) Available drainage

l) Edge Step

m) Edge Erosion

CONCLUSIONS AND RECOMMENDATIONS

(1) All existing roads should be properly inventorised, section by section showing the basic engineering and traffic characteristics of each section of the road network.

(2) Permanent sign posts should be used for entire network without having fixed sign posts it is not possible to identify and monitor the condition of road net work.

(3) It is important to have a road data bank or road register with proper updating and feed back. And all data maintained in a compact form.

(4) Routine maintenance does not necessarily need sophisticated equipments and machinery nor it needs extra ordinary funds, it just requires manual labours attention. Unfortunately attention is not given to routine maintenance activities. It is very rarely observed that routine labour perform their duties.

(5) There should be frequent and objective visual assessment and use of maintenance equipment be made where ever felt necessary for measurement of road condition.

(6) Field offices should be set up at such a distances that a maintenance engineer responsible is able to visit his sight once a week. He must have with him enough equipment to analyse why defects are occurring and to specify what maintenance activity is required.

(7) Various maintenance activities must be carried out in right time as deferring one activity results in rapid escalation of cost. Pre mature application of an expensive activity can only be avoided if an effective and timely maintenance is carried out efficiently.

(8) In maintenance organizations the level of supervision is very low, which gives an opportunity to the labour force to escape away from their duty.

(9) Ordinary routine maintenance expenditures should be determined through a standardised procedure for annual field measurement of quantities based on actual maintenance needs.

(10) Allocation of funds must be based on real needs and by means of over all economic justification of total transport cost.

(11) When we have limited resources we have to work out priority, with the operations that have the strongest claim placed at the head of the list and those that have least claim placed at the end.

(12) The maintenance requirement, identified should be objective and funds may be allocated equitably between the various regions.

(13) There is often a temptation to reduce the amount and scope of data gathering when maintenance funds are tight, this should be resisted where possible as adequate maintenance records are key to credibility.

(14) It is important to define precisely what information is required to meet management objectives and to refrain from asking for more data then is really necessary.

(15) There should be a proper intervention level which must be followed very strictly.

(16) The approach should be to inspect the whole network twice a year which means one inspection during wet season one during dry season. When carriage way is wet defects like surface cracking and drainage are easy to identify.

(17) Pre-printed forms are normally used for inspection as they remind the inspector of items to be considered, the data collected should be recorded methodically kilometer wise.

(18) To work out maintenance strategy and economic evaluation of schemes it is important to know the exact way in which a pavement deteriorates.

(19) Maintenance standards acceptable for road system in a developing country are not necessarily those which would be used in a highly industrialized country.

(20) Roughness should be the principal parameters measured when determining the economic effect of road maintenance.

(21) It is more economical to strengthen while the original pavement still has the ability to function as a structural measure.

(22) There must be limited disruption to traffic, to adjacent land use and limited noise and air pollution during the strengthening/maintenance process.

(23) The organizational structure and management methods used within a maintenance department should be such that they result in the delegation of authority and responsibility to the lowest possible level.

(24) To justify the allocation of funds engineering and economic needs must go together. The cost of vehicular travel is reflected in almost all walks of life, high transport cost means less competitive exports and reduced economic activity.

(25) The policy of diverting maintenance funds to new construction results in Thin spreading of maintenance funds over the entire network which results in wasting of money.

(26) There should be a road maintenance policy a certain part of the road revenue should be spent on maintenance.

(27) Government should encourage the establishment of construction industry. Government organizations should keep planning and control only while execution should be privatised.

(28) Use of contractor in all types of maintenance reduces the burden on staff and can also reduce cost as a result of competitive pressure to efficiency.

(29) In order to improve efficiency there should be a financially self sufficient semi public national highway authority.

(30) Training of maintenance staff should be carried out frequently in order to familiarize them to the latest maintenance equipment and practice.

(31) To be more scientific highway maintenance studies should be more related to roughness measurement, crack and rut formation and skid resistance readings.

(32) Appropriate axle loading legislation must be effectively enforced , it is important to know the actual axle loading for maintenance planning purposes.

(33) It is necessary to create an awareness of the fact that there are reasons to reflect upon the choice of technology and that established technologies do need to be critically examined rather than blindly accepted.

REFERENCES

(1). Development Land Transport - by Grosvenor Press International, UK.

(2). Economic Importance of Road Maintenance April, 1982 - by Mr. M. Sadiq Swati.

(3). Highway Design and Construction - By R J Salter.

(4). Highway Engineering - By CAO' Flaherty.

(5). Highway Engineering - By Laurence I. Hewes & Clarkson H. Oglesby.

(6). Highway Engineering - By Paul H. Wright Randor J.P. Quette.

(7). Highway Maintenance Review (1991-92) - By Sharp Shire County Council, UK.

(8). Maintenance Management for District Engineers - Overseas Road Note-I.

(9). Maintenance of National Highway N-5 (Section Lahore - Multan).

(10). Maintenance of Rural Roads - By OECD (Organization for Economic Co-operation and Development) Paris (1973).

(11). Maintenance of Unpaved Roads in Developing Countries - by (OECD) Paris, 1987.

(12). Maintenance Techniques for District Engineer - Overseas Road Note-2.

(13). Management on Critical Path Precedence Networking Technique (Basic Approach) - by Engineer Abdur Rahim Mian - Project Manager, 1982 NWFP - C&W Department.

(14). National Highway Maintenance Study Vol. I & II - By Kampsax International A/S-1986

(15). National Highways Board, Fourth Highway Project Management Report, 1989.

(16). Pavement Maintenance & Rehabilitation - By Bernard F. Kailas.

(17). Performance Budgeting System for Highway Maintenance Management (National Co-operative Highway Research Programme Report - Washington - 131).

(18). Principles and Practice of Highway Engineering - By L R Kadiyali.

(19). Proceeding of SAARC Seminar on Road Maintenance Materials and Construction Costs (1984) - By National Highway Board.

(20). Relating Pavement Roughness to Vehicle Behavior - By B.E. Quim and E.W. Jones.

(21). Seminar on Maintenance and Drainage Aspects of Road Pavements - By Indian Road Congress (1982).

(22). The Highway Design and Maintenance Standards Volume-III by William D.O. Patterson.

(23). The road maintenance problem and international assistance - By World Bank (1981).

(24). User Benefit from Highway Improvement - by Andrew Chesher and Robert Harrison.

(25). Weekly Crew Scheduling for Highway Maintenance Activities, W.S. Ritchie JR. Commissioner.